INGREDIENT SOLUTIONS IN SPORT AND ACTIVE LIFESTYLE NUTRITION

Sports nutrition is considered to be the foundation of athletic success, achieving fitness goals and improving sport and exercise performance. While following general healthy eating guidelines is important for everyone, sports nutrition can differ from everyday nutrition needs. Sport nutrition strategies typically consider energy, nutrient and fluid provision before, during and after exercise. International sport and exercise nutrition guidelines provide evidence-based advice for the type of nutrient and the amount and timing of intake in order to support individuals' goals in training, recovery and competition.[1, 2]

This paper considers the specific nutrition needs of athletes and regular exercisers, looking in particular at the role of carbohydrates, protein and hydration. It will outline considerations for food ingredient solutions for sports nutrition products that can help achieve optimum performance.

CARBOHYDRATES TO FUEL DAILY EXERCISE NEEDS, AS WELL AS BEFORE, DURING AND AFTER SPORTS

Carbohydrates are recognised as the main fuel in sports performance due to the higher rates of energy provision per volume of oxygen in comparison with fat. Carbohydrates also provide fuel for the brain and central nervous system, conserve protein from being used for energy and provide energy for protein synthesis.[1] They are stored as glycogen in liver and muscle, and depletion of these body energy stores are associated with fatigue during exercise.[3, 4]

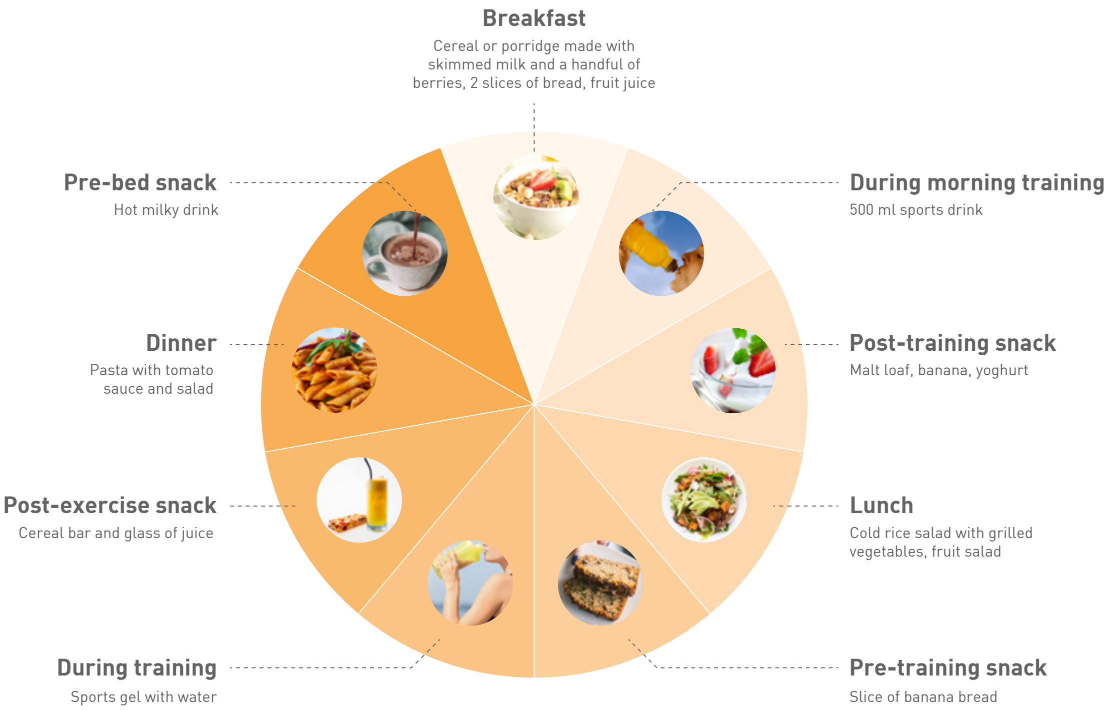
The following sport nutrition guidelines provide advice for daily carbohydrate intake to support day-to-day training which is relative to body weight and which can be adjusted according to the intensity of exercise, type of sport and recovery between sessions (Table 1).[1, 5]

Exercise Intensity	Exercise Examples		Carbohydrate Targets
Light		Low intensity or skill-based activities: Yoga, Pilates, walks and short hikes	3-5 g/kg of body weight (for average person: 210 g to 350 g per day)
Moderate		Moderate exercise programme (e.g. ~ 1 h per day): Jogging, brisk walking, general gym workout, swimming, cycling	5-7 g/kg of body weight (for average person: 350 g to 490 g per day)
High		Endurance program (e.g. 1-3 h per day moderate to-high-intensity exercise): Cross-fit, high-intensity interval training, running, long-distance swimming, mountain biking	6-10 g/kg of body weight (for average person: 420 g to 700 g per day)
Very high		Extreme commitment (e.g. >4-5 h/d moderate to high-intensity exercise: Training for ultra-endurance events such as marathons	8-12 g/kg of body weight (for average person: 560 g to 840 g per day)

Table 1. Guidelines for daily carbohydrate intake (adapted from reference)[1]

Sample meal plan

Sample meal plan for 70 kg person providing ~420 g carbohydrate (6 g/kg body weight) might include the following major sources of carbohydrate:



This menu only lists the main carbohydrate-containing foods and is not intended to represent a complete balanced diet. The menu can be adjusted up or down according to needs by increasing/decreasing portions sizes or by adding/removing carbohydrate-containing foods/drinks. Fibre can be adjusted by looking at food labels and choosing products that provide higher or lower amount of fibre.

Analysed using average portion sizes in Nutritics (2019).[6]

The same guidelines also provide advice for getting enough energy during exercise (Table 2).

Duration	Situation	Carbohydrate requirement	In practice
< 45 min	During brief exercise	Not needed	Not needed
45 - 75 min	During sustained high intensity exercise	Small amounts including mouth rinse (without swallowing)	Carbohydrate in the mouth (via drink or gel) may enhance performance via effects on central nervous system
1 - 2.5 h	During endurance exercise including 'stop and start' sports	30 – 60 g/h	Carbohydrate consumed via sports drinks or energy gels/bars with water
>2.5 - 3 h	During ultra-endurance exercise	Up to 90 g/h provided by glucose: fructose mixtures	Glucose:fructose mixtures consumed via sports drinks and/or energy gels with water

Table 2. Guidelines for carbohydrate intake during exercise (adapted from source)[1]

Guidelines are also provided for the preparation leading up to a competition, sports event or key training session, for example in the hours immediately prior to exercise to maximise body energy stores.

Pre-event meals and snacks help top up glycogen stores or provide glucose early on in exercise, with the choice of food depending on past experience and gastric comfort.[1] This type of fueling practice as preparation for sports is referred to as 'carbohydrate loading' (Table 3).

Situation and example	Duration	Requirement	In practice
General fueling up: Before 10k run	Preparation for events < 90 min exercise	7-12 g/kg of body weight per 24 h	See sample meal plan on page 2
Carbohydrate loading: Few days leading up to a marathon	Preparation for events > 90 min of sustained/intermittent exercise	10-12 g/kg body weight per 24 h for 36-48 h	See sample meal plan on page 2
Pre-event fueling: The morning of a half-marathon	Before exercise > 60 min	1-4 g/kg consumed 1-4 h before exercise.	E.g. yogurt with granola 1-2 h before exercise, or meal of white rice with chicken or chickpeas and vegetables 3-4 h before exercise
Speedy refueling: After a race	< 8 h recovery between 2 fuel demanding sessions	1-1.2 g/kg/h for first 4 h then resume daily fuel needs	For 70 kg person (70-85 g/h) e.g. Slided banana with nut spread on bagel and fruit juice or cereal with milk and piece of fruit.

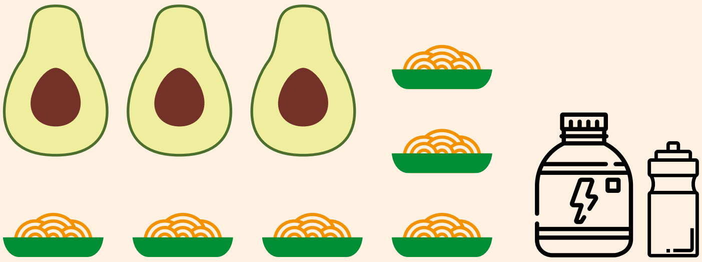
Table 3. Guidelines for carbohydrate intake for preparing for exercise and sport occasions

- **Carbohydrates are recognised as key in supporting performance in high-intensity training and competition.**
- **Choosing the right amount of carbohydrates to match the specific goals of a training session or race helps to achieve better performance.**

New trends: low carbohydrate diets in sports nutrition

'Train low' is a sports nutrition approach where exercise is performed with low body carbohydrate stores. While there is evidence of metabolic adaptation that may be advantageous, there is currently no clear evidence of an impact on sport and exercise performance.[7, 8] Strategies termed 'train low, compete high' and 'training for the work required' have been proposed. These approaches suggest carefully undertaking some lower-intensity/duration exercise sessions with low carbohydrate stores to target metabolic adaptation, followed by a high-intensity/duration session or competition with adequate carbohydrate stores to support performance. Various practical approaches can be adopted in order to manipulate the availability of carbohydrate stores, including: fasting; consuming protein only; and training twice without adequate refueling between – which can either be within a single training day or an evening session followed by a subsequent morning session ('sleep low'). Regardless of the approach, caution is advised before adopting such approaches without adequate consideration and specialist advice, due to the potential risk of various negative effects on health, training intensity and performance.[9, 10]

Train low / Compete high



Marathon build up → **Marathon**

Lower carbohydrate intake → High carbohydrate intake

PROTEIN GUIDELINES TO SUPPORT TRAINING AND LEAN BODY COMPOSITION

It is now generally recognised that athletes and physically active individuals have a higher protein requirement than the general population in order to help maximise adaptation to training and support protein synthesis (body's protein recovery, replenishment and building). Protein is needed not only to synthesise contractile muscle proteins, but also for non-contractile tissues and the cellular structures, digestive enzymes and immunity antibodies which support metabolic processes. Protein synthesis is maximised by the synergistic action of both exercise and protein consumption. The amino acid leucine is specifically recognised as being a key stimulus for protein synthesis.[1, 11]

Suggested daily protein intake for regular exercisers ranges from ~1.2 to 2.0 g/kg body weight[1, 11], although most recent evidence suggests amounts greater than ~1.6 g/kg per day do not provide additional advantages, at least in terms of gains in lean body mass in weight-stable trained individuals.[12] However, slightly higher rates of intake, even up to ~2.4 g/kg per day, are currently recommended to support short-term intensified training loads, and when reducing energy intake to reduce fat mass but preserve lean mass.[11]

In practice, the daily suggested intake typically translates to consuming high-biological-value protein (~0.25 to 0.4 g/kg body weight), providing ~10 g essential amino acids (approximately 20 g of high-quality protein such as animal-based or two or more complementary plant proteins), at regular intervals throughout the day (every 3-5 h or 3-5 eating occasions) and immediately after key exercise sessions.[1]

The effects of consuming protein during exercise are less clear and perhaps less critical, but it may support protein synthesis during resistance exercise or whole body protein balance in endurance athletes.[13, 14] More research is needed for more prolonged endurance exercise, which provides a greater time frame to facilitate muscle protein synthesis.[14]

- Exercisers should consume protein regularly throughout the day in order to stimulate and support protein synthesis.
- The guidelines suggest higher protein intake for athletes than for the general population, although very high intakes may only be necessary during a period of strategic weight loss.
- For regular exercisers, approximately 20 g of protein per eating occasion is recommended every 3-5 h throughout the day and an additional 20 g protein immediately after a training session.

HYDRATION GUIDELINES

As inadequate hydration can impair performance, sufficient fluid intake must be ensured before, during and after exercise so that: exercise is commenced in a state of full hydration; excessive dehydration is prevented; and losses are replaced following exercise in preparation for subsequent exercise.[15] Generic guidelines exist (Table 4) but should be tailored to the individual exerciser and their sweat losses, the environment, the sport, and opportunities to rehydrate.[1, 16]

Situation	Guideline	What does this mean in practice? Example for 70 kg exerciser
Before exercise 2-4 h prior	~5-10 ml/kg body weight	350-700 ml Include some sodium – either via the drink (e.g. a sports-electrolyte drink) or food. Combine with guidelines on pre-event fueling (Table 3).
During exercise	Limit fluid losses to <2% body weight	Typically 0.4-0.8 L/h, but should be adjusted to suit the individual and environmental conditions. To include sodium e.g. via sports drinks, gels or bars. Avoid overhydration (indicated by weight gain during exercise). Combine with guidelines on fueling (Table 2).
After exercise	1.25 to 1.5 L for every L of sweat lost	Estimate fluid loss via loss of body weight and for each kg lost, gradually consume 1.25 to 1.5 L fluid and include sodium via foods or fluids. Combine with guidelines on refueling (Table 3).

Table 4 Guidelines for hydration before, during and after exercise

Other factors which may help to support adequate hydration include considering the temperature of the drink, as cold drinks may be more palatable and beneficial in the heat, and a preferred flavour may aid voluntary consumption.[17]

- **Regular exercisers should plan and practice hydration strategies so that they learn how much they need to consume to support performance and reduce risk of dehydration, especially in the heat.**
- **Nevertheless, exercisers should avoid overdrinking (indicated by weight gain during exercise).**
- **Sodium should be consumed during exercise when it is of a long duration or by people who lose a lot of salt via sweat. Sodium should also be consumed along with fluids after exercise via fluids and/or food.**

INGREDIENT SOLUTIONS IN SPORT NUTRITION

The outlined dietary strategies can, be achieved by consuming everyday foods and drinks. However, situations exist where it may be less practical to consume whole foods and an individual may consider incorporating specific ingredients or sports products as part of their total nutrition strategy. A variety of sports nutrition products are available, including sports drinks, gels, bars, confectionery-type products, protein-containing supplements, and supplements providing specific micronutrients and/or ergogenic aids.

INGREDIENTS TO SUPPORT ENERGY NEEDS FOR SPORT AND EXERCISE

A range of foods, fluids or carbohydrate-containing ingredients which vary in their glycaemic response, effects on osmolality, rates of absorption and fibre content are used to target specific fueling strategies and energy needs for sport and exercise.

Glucose syrups and maltodextrins

Glucose and its polymers provide a rapidly available (high glycaemic index (GI)) source of carbohydrate and are an obvious choice in many sports products. Glucose syrups and maltodextrins can help reduce the osmotic load and/or reduce sweetness of a product compared to glucose alone. Such products can support a maximal carbohydrate oxidation rate of ~1 g/min[18], meaning they help provide a steady supply of energy without causing gastrointestinal distress.

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Glucose-fructose combinations during and after exercise

Consumption of carbohydrate sources which use different transporters in the gut ('multiple transportable carbohydrates') allow for higher rates of absorption and oxidation (Figure 1) and less risk of GI distress, and are associated with better performance in ultra-endurance exercise compared with glucose or its polymers.[19] Most research has focused on glucose-fructose combinations as these sugars rely on different gut transporters, with fructose added alongside glucose or its polymers.

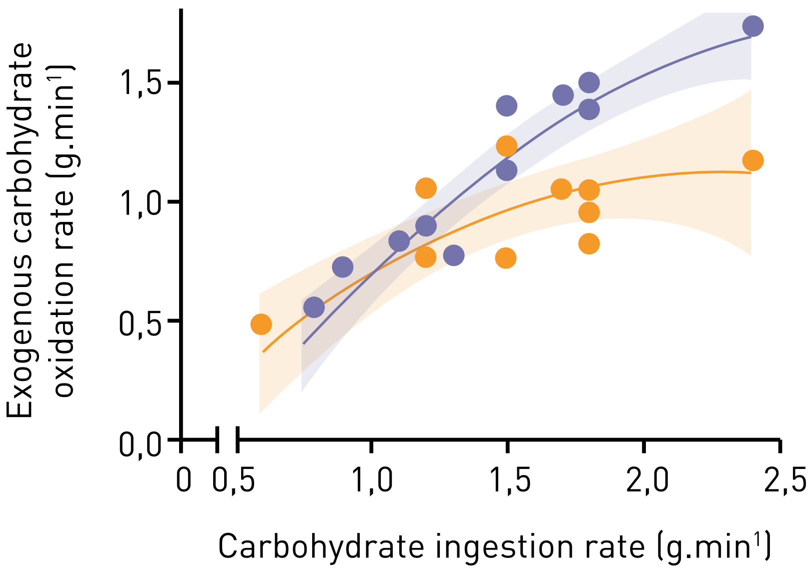

Figure 1. Peak exogenous oxidation rates during exercise comparing glucose polymer (GLU) with glucose plus fructose co-ingestion (GLU + FRU). Each symbol represents the mean from a single study. The shaded areas represent the 95% confidence intervals (adapted from source).[20]

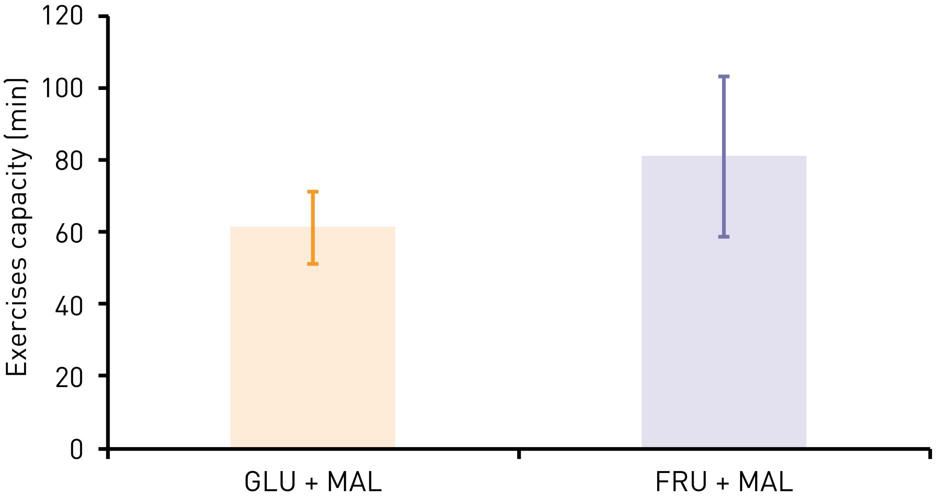

Figure 2. Mean running time in second bout of exhaustive exercise following 4-hour recovery with 90 g/h of glucose-maltodextrin (GLU+MAL) or fructose-maltodextrin (FRU+MAL) ingestion (1:1.5 ratio) (taken from source).[21]

Recent evidence also supports use of glucose-fructose mixtures in post-exercise periods, accelerating restoration of liver glycogen stores without compromising muscle glycogen restoration and improving subsequent exercise capacity compared with glucose alone (Figure 2).[21, 22] This strategy may be of particular importance when rapid recovery is required and may well be reflected in future guidelines regarding 'speedy refueling' (see Table 2).

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Glycaemic response and exercise

The GI of carbohydrates, although currently not considered to have a major effect on endurance performance when conditions are matched for carbohydrate and energy[1], may be of relevance in certain situations. There has been recent interest in the effects of consuming low-GI carbohydrates in situations where there is limited opportunity to consume carbohydrate during exercise. Theoretically, a low-GI carbohydrate provides a slower more sustained availability and higher fat oxidation, with less risk of rebound hypoglycemia (low blood glucose levels) after consumption. Although studies provide support for this theory, effects on performance are less clear and more research is needed.[23] Lower GI in foods and beverages can be achieved by replacing fast-release carbohydrates, such as glucose and maltodextrins, with low GI ingredients, such as fructose, rare sugar (for example allulose) and soluble fibres.

Some athletic populations report an inadequate intake of dietary fibre as recommended for health.[24, 25] This may be due to poor food choices, or to specific strategies to reduce the risk of gastrointestinal disturbances, which are a common feature in strenuous exercise.[26] Conversely, high fibre intake has been associated in other athletic populations with an increased risk of low energy availability.[27] Future research may indicate whether different types of fibre may be better tolerated by athletes, and how athletes may benefit from prebiotic dietary fibre-microbiota interactions, which may include effects on gut barrier integrity, allergy risk, immune system defense and mineral absorption.[28]

- **Fast-acting carbohydrate ingredients such as glucose syrups and maltodextrin are a useful solution for formulating sport drinks and energy products.**
- **Carbohydrates which use different gut transporters (e.g. glucose and fructose) may be of particular interest to ultra-endurance athletes or in situations requiring speedy refueling.**
- **Dietary fibre intakes are generally low in athletes. Adding fibre of good digestive tolerance may be beneficial for athlete's overall health and wellbeing.**

PLANT PROTEIN BLENDS IN TATE & LYLE'S STABILISERS AND FUNCTIONAL SYSTEMS

Most research examining the effects of protein on preserving or increasing muscle mass has focused on single sources of high-biological-value protein, including dairy proteins, egg and soy. Dairy proteins are reportedly particularly good for muscle protein synthesis due to their high digestion and absorption combined with a high leucine content. However, there is growing interest in more environmentally sustainable protein sources, including plant proteins as well as more alternative proteins, for example from pulses, cereals and algae.

Plant proteins may provide a lower level of protein synthesis than animal protein as they generally: appear to be more difficult to digest; may contain various anti-nutritional factors; and contain lower levels of specific EAAs, including leucine. Large differences in essential amino acids (EAA) and amino acid composition have been reported between various plant-based protein isolates[29] (Figure 4). Although more research is needed to determine whether specific strategies can improve the ability of plant proteins to support protein synthesis, several approaches can be taken. These include fortifying them with leucine; adding limiting EAAs; blending different plant proteins for complimentary combinations (Figure 5), or multiple plant proteins; or simply providing higher amounts of plant protein.[30] For some athletes, especially non-elite athletes, a slightly lower rate of protein synthesis may be an acceptable compromise in support of sustainability.

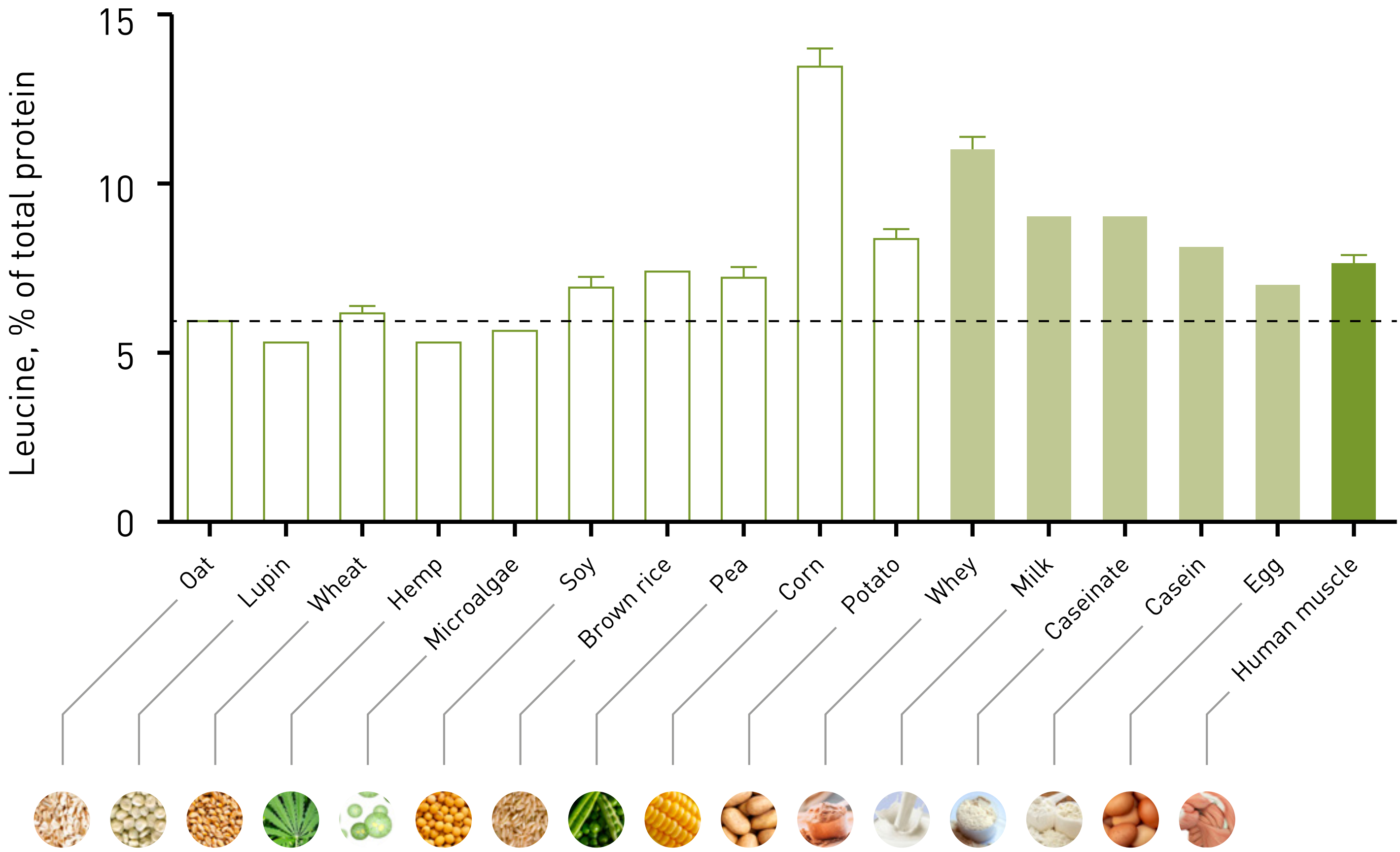

Figure 4. Average leucine content (±SEM) of various dietary protein sources. White bars represent plant-based protein sources, light green animal-derived ones, and dark green human skeletal muscle protein (taken from source.[29]

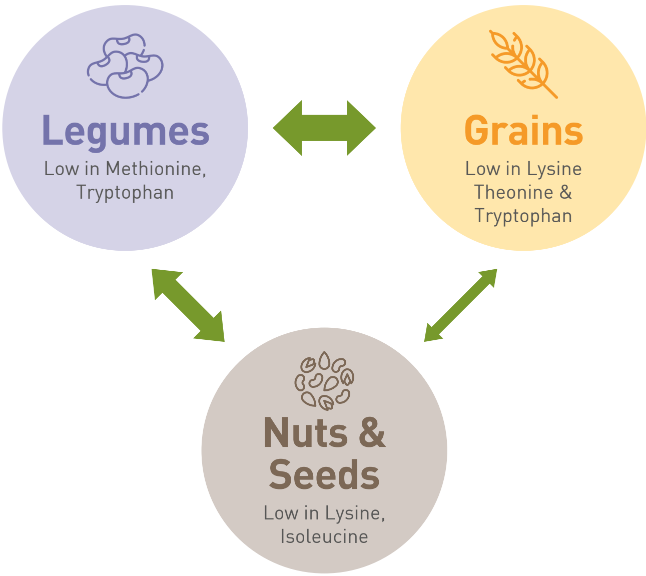

Figure 5. Examples of blending two or more plant protein sources to balance the amino acid profile and optimise protein quality. The thickness of the arrows represent how balanced combinations are likely to be.

Ingredients to promote general health and wellbeing in regular exercisers and athletes

• **Bone health:** Risk of low bone mineral density and stress fractures are a concern in certain regular exercisers.[1] They may be advised to increase dietary calcium intake via the diet or supplements following professional clinical diagnosis and a nutritional assessment. Sports nutritionists and dietitians may wish to take note of recent evidence that soluble fibre increases the bioavailability and absorption of calcium, which may be due to prebiotic-microbe interactions in the large intestine.[31] However, more research is warranted in athletic populations before guidelines can be provided.

• **Immunity:** Avoiding illness is a major concern for athletes as it limits their ability to train and complete. A recent consensus statement on immune-nutrition and exercise provides little support for nutritional intervention in maintaining athlete immune health.[32] Of the immune-supporting supplements that are commonly promoted, the ones that attract a moderate level of support for evidence of efficacy include: prebiotics, probiotics, and vitamins C and D for reducing incidences of upper-respiratory tract infections (URTIs); and zinc for reducing the duration of URTI symptoms.[1, 32] However, further research is warranted, and athletes should seek professional guidance regarding their efficacy and the balance of risks vs. benefits in order to make an informed choice.[1, 2]

• Emerging research areas in sport and exercise nutrition include:

- specific strategies to improve the ability of plant proteins to optimise protein replenishment for exercise;

- which athletes are at risk of an inadequate consumption of fibre, whether any specific fibres are better tolerated by athletes, and whether they can provide prebiotic benefits to regular exercisers.

PRACTICAL CONSIDERATIONS WHEN CHOOSING THE RIGHT SPORTS NUTRITION PRODUCT FOR THE RIGHT EXERCISE OCCASION

EXERCISE OCCASION	PRACTICAL EXAMPLES			PURPOSE
BEFORE	Electrolyte water	Carbohydrate rich snack	Carbohydrate rich breakfast	• Hydrating • Fuel top-up • Preparing for a high-intensity session
DURING	Electrolyte water	Sports drink	Glucose:fructose gel	• Staying hydrated • Sustaining energy needs
AFTER	Bottle of water	Vegan protein shake	A meal of meat (e.g. chicken), rice and vegetables	• Replenishing • Rehydrating • Recovering • Coming back to your best
ANYTIME	Yoghurt	Rice cake	Cereal bar	• On the go • Energising for longer • Protein hit

CASE STUDIES

1. I want a drink that quenches my thirst and supports the refuelling and adaptation to exercise processes.

Solution: The drink needs to provide ~20 g of high-quality protein, such as dairy, two or more plant proteins, ~70 g of carbohydrate and, some sodium to help retain the fluid.

2. I want a drink that is flexible in terms of concentration, depending on whether the focus is on hydration or fuelling during long training sessions.

Solution: The drink is in powder form containing glucose and fructose (1:1 ratio), with instructions on how to make up drinks in order to provide an amount of carbohydrates ranging from 30 g/h through to 90 g/h, together with small amounts of sodium.

3. I want a snack which is healthy, easy to digest and helps me get through the afternoon so I feel ready to head to the gym straight from work.

Solution: The snack contains ~70 g of a lower-GI carbohydrate together with some sodium and a small amount of fibre to increase fibre intake for the day.

CONCLUSIONS

Nutrition in sports and exercise differs from daily nutrition to help achieve fitness goals and to improve performance.

Most sport nutrition recommendations can be met by following healthy eating guidelines and incorporating whole foods, drinks and specialist sport nutrition products.

Contact **Tate & Lyle's Global Nutrition** team to learn more about the science behind ingredient solutions for sport and exercise nutrition, and reach out to your sales representative or technical application scientist to learn more about how Tate & Lyle ingredients can be used to formulate sport nutrition foods and beverages that consumers will love.

Disclaimer

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